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Analyzing the Interaction of Neutrons for Cancer Treatment Purpose

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ABSTRACT

In this paper, a new analytical method is studied for cancer therapy by neutron. This method can be used for all tissues and investigations in regard to cancer therapy. The analytical method is considered using mathematical equations and computer programming. The amounts of Kerma are calculated by mathematical method in a liver tissue for a wide range of energies because of collision between a neutron beam with nuclei of constituent elements of tissue which have various mass numbers. In the case of lack of clinical neutron source in eligible energy for radiation therapy by neutron, this method might be applied to calculate the energy of neutrons reached the eligible energy range through deducing the incident neutron energy emitted from clinical neutron source for a vast spectrum of neutrons. In addition, by this investigation, the required irradiation time for radiation therapy of tissue might be obtained according to both neutron flux and energy of existing clinical neutron source.

KEYWORDS: Kerma; Mathematical; Neutron; Radiation; Therapy.

1. INTRODUCTION

Radiation therapy is a technique that has been designed to treat tumors through high LET heavy charged particles radiation at the cellular level [1]. The concept of radiation therapy by neutron first was shortly proposed after the discovery of the neutron by Chadwick in 1932, and the elaboration of the unusually large thermal neutron capture cross section for natural isotope ^{10}B by Goldhaber was done in 1934. He discovered that ^{10}B has an unusually high avidity to absorb either slow or thermal neutrons (for E <0.1eV) [2].

It is considered that reactor based epithermal neutron beams with near optimum characteristics are currently available, and more can be constructed at existing reactors. The suitable reactors those which include low power reactors generally, using the core as a source of neutrons and also existing moderator might be used for radiation therapy if the neutrons are difficult to access [3, 4]. The boric acid solution moderator might be suitable for the spectrum measurement of an epithermal neutron irradiation field [5]. Thus computation and modeling of the delivered energy by Monte Carlo method before practical treatment is also recommended [6]. In this research, there are two prime objectives. These objectives are:

First of all is calculation of the amount of Kerma in the liver tissue within the course of radiation therapy by neutron.

The second objective is to find out a way to reach eligible energy range of neutrons according to desired dose in radiation therapy and also studying the deduction of incident neutron energy emitted from neutron source for a vast spectrum of neutrons so that it can specify the accurate amounts of Kerma and neutron energy reached components of a tissue during the therapy, and subsequently obtaining the required irradiation time for radiation therapy. According to figure 1, the structure of an actual liver tissue of human has been illustrated [7]:

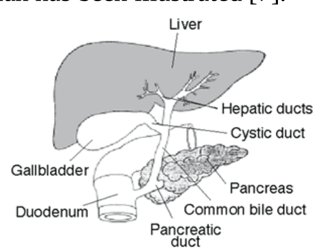

Figure 1. The perfect view of a human's liver tissue

The different shapes of tissues like, cubic format for body parts of human in some research have already been applied [8]. A liver tissue includes substances such as water, glycogen and heavy molecules like protein and glucose. But in general, in such kind of research, the main aim is to simulate the nuclear and atomic interactions in the material, hence the geometry has minor importance [5, 9].

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2. MATERIALS AND METHODS

2.1. Application of mathematical method

In a laboratory system, due to having collision between a neutron and a nucleus, the amount of energy transferred to a recoiled nucleus is computed with Eq.1 [10]. In fact, the Eq.1 is defined from viewpoint of laboratory system.

$$E_R = \frac{2A}{(A+1)^2} E_n \cos^2 \psi \qquad (1)$$

Where:
E_R: the energy of thermal neutrons which have reached the eligible energy
A: mass number of the components of the system
E_n: Energy of incident neutron
ψ: The angle between the course of projectile neutron and recoiled nucleus in laboratory system

For neutron energy greater than 8MeV, (n,α) reactions play very preponderant role among all the reactions so that in this state some part of Kerma is due to α particles.
In this state, the calculation is carried out using neutron angular distribution after scattering and random sampling of neutron collision in either elastic or inelastic scattering,
The atomic composition of the soft tissue is approximated with hydrocarbon materials. In the investigation, neutron slowing down has been taken into account as well.
Equation 2 shows the exponential decrement of neutron energy because of passing across the tissue [10]:

$$E_R = E_n e^{-n\xi} \qquad (2)$$

Where:
ξ: Lethargy
The Eq.3 is obtained based on the Eq.2:

$$E_R = E_n e^{-\left(\frac{\Sigma_a + \Sigma_s (1 - \frac{2}{3A})}{\Sigma_{sl}}\right) \times \left(\frac{2}{A + \frac{2}{3}}\right)} \qquad (3)$$

Where:
Σ_a: cross section of absorption
Σ_s: cross section of scattering
Σ_{sl}: cross section of slowing down

Therefore, to calculate Kerma in the tissue, the energy range is parted, and then the obtained value is added to previous amount of energy, as below:

$$E_{R(new)} = E_R + \frac{E_n - E_R}{n} \qquad (4)$$

Where:
n: The collision number

Therefore, according to Eqs.3 and 4, the amount of Kerma in the tissue is obtained. In order to reach the required absorbed dose according to energy of neutron source, using the Eqs.3, 4, the amount of Kerma in the mentioned tissue is obtained. The Eq.3 is defined based on mathematical equations, and thereby the irradiation time can be obtained to reach the eligible KERMA so that it might be applied for a patient who sets under radiation therapy by neutron.

3. RESULTS

The amount of Kerma is calculated because of emitting a neutron beam with constituent elements of tissue having various mass numbers (a wide range) per the mass number of constituent elements of it. The derived results are illustrated in figure 1 through mathematical method:

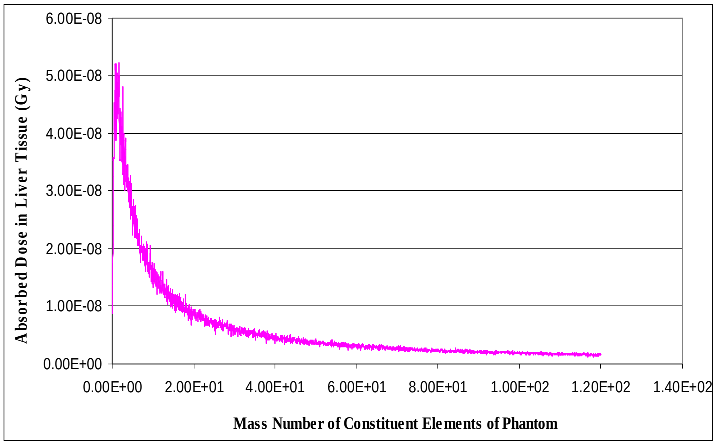

Figure 1. Amounts of Kerma for a wide range of mass numbers calculated by mathematical method

The amount of Kerma is calculated in the mentioned liver tissue (including water, glycogen, protein and glucose). The derived results are illustrated in figure 2 for a wide range of energies:

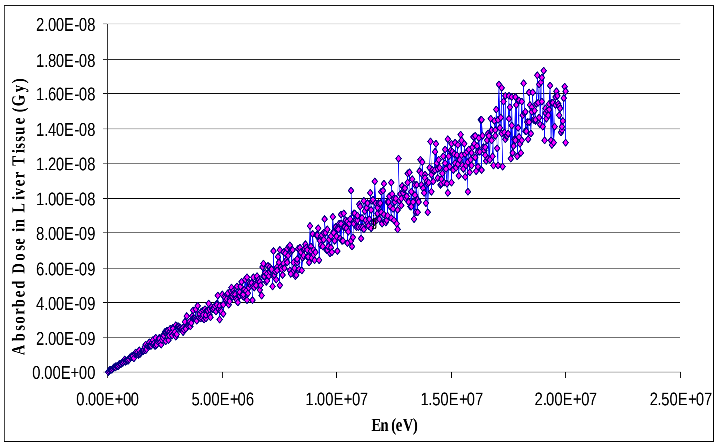

Figure 2. Amounts of Kerma in the liver tissue for a wide rage of energies calculated by mathematical method

4. Conclusion

The analytical method provides dose calculation based on mathematical equations and considering ψ and E_n despite having been carried out the calculation based on neutron tracking and transport equation in MCNP code.

By the mentioned method, it can be inferred that how much time as the required irradiation time will take till the desired dose is reached for treating liver cancer by radiation therapy for each of real liver tissues, which have various dimensions and compositions.

After reaching the eligible energy of neutron, according to determination of the required dose (Gy) by related expert like, radiobiologist for treating a patient through radiation therapy by neutron and also based on the reached energy (MeV), the required irradiation time to reach the desired dose for radiation therapy of each of real liver tissues, which have various dimensions will be inferred. Therefore for each patient, through knowing the desired dose for therapy and also specifications of neutron source (energy and flux), the required irradiation time for similar liver tissues is obtained.

As it is observed in figure 1, the maximum Kerma occurs for elements having small mass number like hydrogen. It means the most amounts of Kerma are related to liver tissue because of abundance of hydrogen in it. The figure 2 implies that with higher neutron energy, more doses may be delivered to the liver tissue.

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